APPENDIX D

Summary and Analysis of:

"Effects of the Disposal of Seawater Desalination Discharges on Near Shore Benthic Communities"

Prepared for

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Introduction

This is a review of the scientific and technical information contained in "*Effects of the Disposal of Seawater DesalinationDischarges on Near Shore Benthic Communities,*" a draft report, dated 1 April 1998, that was authored by Mark A. Hammond, Norman J. Blake, Craig W. Dye, Pamela Hallock-Muller, Mark E. Luther, David A. Tomasko, and Gabe Vargo.

The combined expertise of these authors is in the areas of marine biology, marine and coastal ecology, coastal engineering, and environmental science. Many of them have a professional association with the report's sponsoring agencies: Southwest Florida Water Management District, University of South Florida.

The report describes research evaluating the biological and other effects of the concentrated seawater discharge from a Reverse Osmosis (RO) seawater desalination facility located on the Caribbean Island of Antigua. This research was a fundamental aspect of the environmental pre-planning studies conducted prior to construction of a high capacity RO plant at Tampa Bay, Florida.

What is in this Report?

It describes results of a field reconnaissance of apparent biological and other effects resulting from discharge of the concentrated saline water by-product from the Culligan Enerserve RO desalination plant operating on the Caribbean Island of Antigua. Antigua, which is in the Lesser Antilles Island chain of the West Indies, is located about 300 miles south-southeast of Puerto Rico.

RO Plant Specifications

Located on Antigua's eastern shore along Crabbs Peninsula and adjacent to Parham Harbor, the Culligan Enerserve RO plant has been operating since 1993. It has a freshwater production capacity of 1.32 million gallons per day (mgd) and uses Parham Harbor surface water [salinity 35 parts per thousand (ppt)] for its source water. The RO plant's by-product, about 1.8 mgd of concentrated (57 ppt) seawater, is discharged into Parham Harbor.

These specifications, in addition to a discharge area that contains a healthy and diverse biological community (with many similarities to Tampa Bay) made the Antigua RO site a desirable study area. Also, and perhaps most important, the research team was able to manipulate the RO plant's discharge to suite the experimental objective of obtaining baseline data on a marine habitat's physical and biological status before and then during a period when it was exposed to the concentrated seawater discharge.

Since it began operation, the Antigua RO Plant has discharged its concentrated seawater by-product into Parham Harbor via an elevated rectangular concrete flume extending to the water's edge (Figure 1). Depending upon tidal height (daily range in Parham Harbor is 0.25 m), this discharge either spills directly into the water or flows to the water's edge across a 3-5 m strand of exposed beach and rock.

What experiment was done?

The authors of this study received permission to temporarily change the discharge site. By installing a plywood stopper and flange over the end of the flume and there attaching a 12 inch PVC pipe, the discharge point was extended 20 m (about 60 ft) out into Parham Harbor. Figure 1 shows the position of the discharge pipe relative to the RO plant and a large jetty. The pipe's end was capped and a discharge port was formed by cutting a 12x12 inch (0.3x0.3 m) saddle notch on the pipe's upper side.

Diversion of the discharge was done in March 1997. In the days (22-29 March) prior to the diversion, investigators conducted baseline, pre-salinity exposure studies of the habitat that would receive the concentrated discharge. The objectives were to census the study area and describe its water quality. It was necessary to establish that the site was biologically representative of the habitats and environmental conditions generally present in Parham Harbor. It was also important to confirm that the site was not contacted by the pre-existing RO shore-discharge plume.

Environmental effects of the newly established discharge site would be assessed by comparing the "pre-discharge" state with conditions found at three month (June 22-26) and six month (October 1-6, 1997) post-diversion site surveys.

How was the environmental survey conducted?

The discharge study area was mapped and six linear transects, extending radially 10 m out from the center (=discharge site), and at 60 degree angles from one another, were marked at one- or two-meter increments using PVC stakes and tags. As seen in Figures 1 and 2, transect lines reflect compass headings and are numbered clockwise beginning nearest to North. Transects extended both on- and offshore from the discharge site. Transects II and IV were approximately parallel to the shoreline. Water depth at the discharge-pipe opening was about 1.2 m and the opening, a rectangular (0.09m^2) notch on the pipe's upper surface, directed discharge up to contact water surface. Three transects extended off shore into moderately deeper water and three went into more shallow water. Maximum water depth at the termini of the three most near-shore transects ranged from 0.7 to 1.1 m. The depth range at the outer end of the three most offshore transects was from 0.8 to 2.6 m. Together, the six transects define a 20x20 m (400 m^2) area centered over the discharge-pipe opening. This study area was used to map topographical and other physical features as well as discharge-water contours.

Water quality was assessed using a Hydrolab system and by noting in particular the distribution of the three principal RO discharge "signals," increased temperature, lowered pH, and increased salinity. Monitoring was done on rising and falling tides and at different times of the day. Tidal current flows were recorded and dye was injected at the flume to observe discharge cohesiveness and distribution.

Figure 2 shows transect locations for the Hydrolab and biological sampling. The Parham Harbor study area contains a diverse assemblage of healthy marine organisms including sea grass (*Thalassia*), algae (*Dictyota*) hard (*Porites*) and soft (*Pseudoterogorgia*) corals, and an association of tropical microalgae, micro- and macro-invertebrates, and fishes. In addition to a census of the principal species in this community, the plan was to also compare the pre-diversion abundance and condition of these organisms with their status after three and six month's exposure to the concentrated seawater discharge.

Using SCUBA and snorkeling, transect surveys were done to both count individual organisms and map the distribution of sea grasses, algae, and epibenthic macro-invertebrates. Divers also took sea grass and algal samples for laboratory analysis. Substrate samples (mainly coral sand) were taken using core or "grab samplers" and small syringes (modified for coring by cutting off their tips) in order to determine the types and relative abundances of benthic microalgae (including diatoms), of benthic foraminifera (small amoeba-like single celled animals with calcareous shells), and of infaunal (i.e., living within the substrate) macro-invertebrates. Plastic settling plates (also termed fouling plates), were attached to the substrate along the transects. These plates are inert surfaces that enable censusing of the types and numbers of organisms that are recruited (i.e., planktonic plant spores or animal larvae that drift into the area, settle out of the plankton, attach to the plate and become established) over a specific period. Divers also recorded the presence of fishes and mobile invertebrates (i.e., starfish, anemones, snails) on the transects.

Collected samples were either frozen or preserved and returned to the laboratory. Substrate samples to be assayed for diatoms and foraminfera were immediately injected with a vital stain (Rose Bengal), which colored and preserved the tissues, thus making it possible to distinguish organisms living at the time of collection from their empty (dead) skeletons. In the laboratory, samples were analyzed microscopically to assess the growth status of sea grass, to count and classify the diatoms and foraminifera (and differentiating the living and dead) and enumerate and classify the infaunal macro-invertebrates. Measurement of the substrate content of the photosynthetic pigment chlorophyll a wasused as a proxy estimate of substrate microalgae concentration.

What are the Report's findings?

A. Physical conditions.

Pre-diversion water samples confirmed that water from the RO shore plume did not flow into the study area. Three features of the RO discharge water, elevated temperature and salinity and a reduced pH, were all detectable within the study area. The small differences between discharge and ambient water (discharge water was 2-3°C warmer and its pH was 0.2-0.3 units lower) were rapidly dissipated by mixing. Dye injected at the flume demonstrated the discharge plume's tendency for rapid dissipation and for movement towards deeper water (because it is denser it sinks). Depending upon bottom topography and contour and current flow, divergent pH and temperature values were rarely detected beyond 2-6 m from the discharge-pipe opening.

The large difference between discharge and ambient salinity (57 vs 35 ppt) resulted in a stronger salinity "signal," which was detectable beyond the 10 m study area and distributed mainly down slope. Maximum bottom salinities, recorded in the immediate vicinity of the discharge opening, were 35-40 ppt in June and 34-38 ppt in October. Because the pipe discharge flowed upward and contacted the surface, surface salinities were higher (35-44 ppt June, 34-43 ppt October). However, and because of strong mixing, salinities at the 8-10 m transect positions averaged only 0.2 ppt above ambient, with salinity increases extending farther down slope than up slope.

B. Biological status.

Studies of the sea grass beds indicated no changes in their health (as reflected in the number of "new shoots"), abundance (biomass) and growth rate (productivity) over the three survey periods. There was thus no effect of concentrated saline exposure. Also, the levels of salinity measured in the study area are well below the levels (about 70 ppt) known to cause permanent cell damage to sea grass. All sea grass plants studied in all transects showed a high degree of parrotfish bite scarring which indicated that this foraging fish frequented the study area in spite of the concentrated salinity discharge.

Algal abundance was generally variable over the three sampling periods, however, this variation is not correlated with the discharge salinity. One brown alga (*Dictyota*) did show variations in its growth rate and a weak correlation was found for its growth rate and salinity. Tissues from plants living within the study area also showed a higher concentration of nitrogen than did plants sampled from outside the study area. Reciprocal transplant studies, in which *Dictyota* specimens from within the study area were moved out and plants living outside were moved in, failed to induce a nitrogen increase in the newly introduced study area residents and there is thus not conclusive evidence for a discharge-salinity effect on *Dictyota.* It was concluded that perhaps episodic chemical imbalances associated with excessive rainwater runoff (storm culverts flow into the flume and surface runoff mixes with the RO discharge) or possibly caused by either RO membrane servicing or RO system flushing may have affected the chemistry of *Dictyota*.

A greater concentration of substrate-dwelling microalgae (as indicated by greater chlorophyll a amounts) was found in June and October compared to March. However, because there was no trend within or along the transects, this suggested that a factor other than the saline discharge had triggered the microalgae concentration increase. Diatom numbers and types did not change from pre-diversion conditions in either sampling period or along any transect.

Benthic foraminifera occurred on all substrates including sea grass blades. Their distribution and abundance varied considerably within the study area, however, comparison of the pre- and post-diversion surveys showed no differences that related to the presence of the concentrated seawater discharge. Also, because foraminifera are considered reliable indicators of habitat health state, the absence of pre- and post-diversion changes for this group suggests the habitat was not stressed.

The benthic invertebrate infauna collections totaled nearly 37,000 individuals, distributed among 339 different kinds (taxa), that included sponges, coelenterates, annelid worms, mollusks, arthropods, peanut worms, echinoderms, and chordates (tunicates). Of the 339 taxa about 10 species accounted for 52% of the infauna. These dominant organisms included seven species of annelids and one species of snail. However, there were significant differences in the infaunal assemblage (i.e., both the absolute numbers and relative abundance of the dominant species) at different times. The March and October samples each had more animals than did the June sample. These differences in infaunal invertebrate abundance and diversity did not appear affected by elevated salinity.

The June and October settling plates documented the arrival of nearly 1800 individual animals representing 12 different taxa. Bryozoans and polycheate (annelid) worms were the dominant forms with hydroids, snails, clams, and sea urchins also settling. A large influx of hydroids occurred in June but not in October. However, overall variations in the groups that settled on the plates at the different sampling times was attributed more to biological factors (reproductive season, productivity, etc.) than an elevated salinity effect. Because there was no pre-diversion settling plate data, it is unknown whether or not increased salinity excluded any species from settling.

Benthic macro-invertebrates observed by divers in the study area included hard (*Porites*) and soft (*Pseudoterogorgia*) corals, the great anemone (*Condylactus*), the cushion starfish (*Oreaster*), and the queen conch (*Strombus*). *Porites* colonies living near the discharge pipe in salinities about 5 ppt above ambient survived the entire study period. The mobile macro-invertebrates such as *Strombus* and *Oreaster* were frequently observed in close proximity to the discharge pipe.

Thirteen species of fish were recorded in the study area. The two most abundant species were the bucktooth parrotfish (*Sparisoma*) and the yellowtail snapper (*Ocyurus*). More species occurred in a deeper part of the study area, about 6-10 m away from the discharge site, where there was more rocks and greater vertical relief. There were no obvious or statistically significant effects of the saline discharge on either the macro-invertebrates or fishes in the study area or among the different observation periods. Both the fishes and mobile invertebrates appeared to move through the area independent of the salinity discharge profile. Parrotfish tooth scars on the sea grass plants in the study area confirm the regular appearance of this species.

What are the Report's Main Conclusions?

- The RO concentrate is rapidly dispersed and dissipated and salinity returned to ambient within a small distance of the discharge.
- There was not a salinity "build-up."
- The discharge area over which pH and temperature differ from ambient was much smaller than that of salinity.
- Study area transect surveys done before and then three and six months after diversion showed no discernable effect of RO discharge on the density, biomass, or productivity of the seagrass. Also, the number of seagrass shoot densities, an index of plant health and viability, did not differ before and six months after discharge diversion.
- The discharge had no effect on the feeding behavior of a major seagrass forager, the bucktooth parrotfish.
- The discharge had no effect on the abundance or the apparent health status (as indexed by chlorophyll concentration) of the benthic microalgae.
- Neither the abundance nor the diversity of the substrate-occurring diatoms was affected by the concentrate discharge.
- Benthic foraminifera were similarly unaffected by six month's exposure to the concentrated seawater discharge.
- Foraminifera are generally considered indicators of environmental quality. If the types and relative abundances of foraminifera in the study area did not change, this implies the salinity discharge was not having a large effect.
- Adverse responses to the seawater concentrate discharge, by either large invertebrates or fishes, were not observed by divers. Transect data similarly indicated no area-avoidance behavior.

- Divers commonly observed two mobile invertebrates, the queen conch and the cushion starfish within the areas of maximum salinity.

- Coral heads located within the transect area and exposed to an average salinity elevation of 4.5 ppt showed no ill effects over the entire 6 month observation period.

- Settling plates indicated the recruitment of a number of species into the area over the course of this study.

- The presence of both starfish and sea urchins in the elevated salinity study area is notable in light of the general perception that these animals (and all echinoderms) have a low tolerance for seawater salinity change.

What are the Report's most positive features?

- An experiment was conducted in which it was possible to evaluate a habitat before and after introduction of a concentrated seawater discharge from an RO plant.

- The team of expert scientists assembled for this study made careful observations of the "pre-" and "post-diversion" effects. They planned and executed a detailed sampling program to quantify the physical factors in the habitat and the response of the biota (in terms of both community structure and the relative abundances of major species) to the concentrated seawater incursion.

What are the Report's limitations?

- The sampling periods were limited to only two post-diversion observations and extended only six months post-diversion.

- This period is too short to determine how other variables such as season, rainfall, and nutrient presence and annual nutrient cycles, and biological cycles of recruitment and production influence the Parham Harbor marine community.

- Rains, for example, occur mainly in two seasons of each year (January-February) and (September-October), and a longer study period would be needed to assess this effect.

- The time limitation is further illustrated by the fact that the settling plate studies reported did not have "pre-diversion" control data. Plates gathered in June reflected study area colonization since March. Those collected in October indicated the combined settling history of six months. However, no plates were available to show recruitment between October and March and therefore a contrast between pre- and post-diversion settling cannot be made.

- Monitoring of a second "control" site, where no salinity changes occurred, would have provided important baseline data for interpretation of the possible causes of some of the small biological changes recorded within the study area.

What relevance does this Report have for proposed operations at Huntington Beach?

A. Reference Information.

1. The Antigua report reviews existing literature pertaining to RO discharge effects on marine biota, pointing out that very little is known.

2. Most of what is known is contained in technical reports and, for this reason, is not as directly accessible as data appearing in the more widely distributed journals.

B. The finding of no salinity effect.

1. The Antigua report provides a diverse number of broadly based observations documenting the lack of an effect of a rather large salinity anomaly on a tropical reef community.

2. "No effect" has also been predicted for the Huntington RO discharge which will be less extreme, in terms of the salinity differences between the discharge and ambient water, than Antigua.

C. Differences in the Antigua and Huntington RO plant and discharge systems.

1. The Antigua concentrate flows directly into the ocean (57→35 ppt).

2. The Huntington Beach concentrate will mix with power-plant cooling water and become highly diluted before entering the ocean. At a typical operating level of 250 mgd, the "in pipe" dilution factor is 200/50 = 4, which means that 57 ppt will be diluted toward 39 ppt before the discharge reaches the ocean.

3. Both Antigua and Huntington Beach have upward directed, surface contacting discharges, which promotes rapid water mixing.

4. The Huntington Beach discharge volume (at least 200400 mgd with 50 mgd of RO water) greatly exceeds that at Antigua (1.8 mgd). Not only does the dilution factor minimize the salinity effect on the environment, because of tidal and coastal currents there is a much

greater volume of open and moving water surrounding the Huntington discharge which will further enhance the plume dissipation.

D. Biological contrasts for Antigua and Huntington Beach

1. Antigua is tropical. Huntington Beach is not.

2. The Antigua Parham Harbor reef study area is complex having rocks and a notable vertical relief and a large benthic species diversity including corals, sea grass and algae.

3. The area around the Huntington coding discharge is a flat sand and mud scape. It is structurally less complex, having less vertical relief and having no corals or sea grasses and very little if any benthic algae.

4. Because the sandy and mud bottom around the Huntington discharge lacks complexity there is a much lower abundance of benthic macro-invertebrates.

5. The infaunal diversity at Antigua and at Huntington Beach is expected to compare favorably, however, the species list for the two habitats would differ considerably if not entirely.

6. As has been documented for the Antigua study area, it is expected that macro-invertebrates and fishes that enter the seawater concentrate discharge area will not be affected by it and will not purposely avoid the area.